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Defining virtual, augmented and mixed reality in physiology education

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Over the past decade, a large portion of my time has been spent working on integrating technology into physiology teaching. It has been an enjoyable and rewarding journey, especially learning how to create virtual models of organ systems and anatomical structures for students to navigate through using devices such as virtual, augmented and mixed reality. In March 2020, when social distancing was enforced and teaching conducted online, our team immediately thought it would be fantastic to convert the virtual reality lessons into online sessions to engage students within their homes. However, we soon realised that although technology can theoretically allow for learning at any time in any place, this often needs to be a specific goal during the lesson's creation. Only one of my students owned a virtual reality headset, and no-one had access to the mixed reality device I'd been planning to use, the Microsoft HoloLens, rendering these lessons unusable. As such, we had a completely virtual, engaging and interactive series of laboratories and physiology learning sessions that were completely unusable outside of the laboratory environment (Fig. 1).

The need to run classes off-campus certainly helped to motivate the conversion of many teaching resources into entirely online delivery. I am very grateful to have received the 2019 David Jordan Teaching Award to help share as many physiological resources and online learning tools as possible, and this placed me in good stead for creating a wide range of online physiology curricula. I have now been teaching through a variety of modes that are entirely free for students, such as using Instagram (@physiologywithchristian) to run informative sessions, YouTube for video content (Physiology with Dr Christian), and trialling different forms of educational media, such as converting my Physiology and Anatomy adventure game into a completely free fully online platform (**https://www.physiologywithchristian.com/game** - check it out!!).

As integrating virtual, augmented and mixed reality into our physiology classes has been a recent highlight for teaching, I thought it might be helpful in this article to explore these terms and their use in the literature.

What is virtual, augmented and mixed reality?

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Virtual reality, augmented reality, mixed reality, extended reality, and cross-reality are all widely contested terms. The most helpful source from the literature to decode some of these terms is an article by Milgram and Kishino (1994). Here, the authors describe the use of a "Reality-Virtuality Continuum". In their model, one end of the spectrum is the real environment, with the other end the virtual environment (i.e. virtual reality). Augmented reality fits in the middle, while mixed reality is employed as a somewhat *umbrella* term encompassing the entire spectra. With the introduction of new devices explicitly marketed as "mixed reality", this definition may be ageing, so I've done my best to summarise these terminologies below:

Virtual reality: The user's senses (sight, hearing and motion) are fully immersed in a synthetic environment that mimics the properties of the real world through high resolution, high refresh rate (constantly-updating) head-mounted displays, stereo headphones and motion-tracking systems (Moro *et al.*, 2017).

Augmented reality: Using a camera and screen (i.e. smartphone or tablet) digital models are superimposed onto the real-world. The user is then able to interact with both the real and virtual elements of their surrounding environment (Moro *et al.*, 2017).

Figure 1. Students in Christian's class using virtual reality to explore the structures of the spine.

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Mixed reality: While augmented reality overlays digital information onto real-world elements, mixed reality allows for an additional layer of interactivity. Virtual objects placed within a mixed reality environment can be interacted with as if they were real objects. The user's hand and feet, as well as other people, become part of the environment in which all objects, real and virtual, are fully interactable (Birt *et al.*, 2018).

There remains some overlap between augmented and mixed reality, and as such, other contemporary umbrella terms have been increasingly present in the literature. In particular, the use of "XR" is a modern way to group all the modes together, even if the acronym's components remain contended. XR may represent: cross-reality; extended reality; or simply "X"-reality; but either way, having a single term to discuss these modes has been useful.

Which "reality" mode is best for physiology teaching?

This question is tricky to answer, as each mode is unique and holds its own benefits. Virtual reality provides a fully digital environment, placing the user's eyes, ears, hands and body within a completely artificial space (Kuehn, 2018). For example, virtual reality has allowed me to create a large pair of lungs that enables students to walk inside and see the features surrounding them. On the other hand, augmented reality can be beneficial if you wish to add interactive features, such as a beating heart, to silicon models or laboratory resources. Recently, I've developed a real interest in exploring mixed reality, with this current semester set to mark the introduction of lessons using the Microsoft HoloLens. This is a new device capable of blending the benefits of both virtual and augmented reality in a head-mounted computer (Fig. 3). While this rollout has currently been delayed due to world events, once we are all back on campus, I'm very excited to see whether this technology is effective for learning.

Associate Professor Christian Moro is the Science Lead of the Bond University Medical Program and a urological researcher, investigating the physiology of the lower urinary tract. Christian also develops and researches evidence-based resources for medical and health sciences, such as the use of Instagram (@physiologywithchristian) and YouTube (Physiology with Dr Christian) for physiology education.

Figure 2. Students in Christian's class using augmented reality to learn about the physiology of the brain and central nervous system.

Figure 3. Students in Christian's class using the Microsoft HoloLens, a head-mounted mixed reality device, to learn the physiology of the cardiovascular and pulmonary systems.

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Making the most of online learning in lockdown: A student perspective

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On 12 March, universities across Ireland were forced to close their doors in an effort to control the spread of SARS-CoV-2 virus. This impacted hugely on education, presenting both opportunities and obstacles to learning for all students including myself. As a third-year physiology student, I was now forced to alter my study regimen and contend with an uncertain format for examinations.

Online learning, especially in higher education, has become more prevalent over the last few years; however, the COVID-19 crisis has forced institutions at every level of education into a paradigm shift in teaching and learning. Traditional face-to-face learning, as we know it, has been abruptly truncated, and we have all had to adapt to new learning styles, and a new "normal." The rich learning experience afforded to us by conventional classes has been drastically diffused and we have suffered from the absence of practical laboratory classes, tutorials and lectures. Conventional learning prior to COVID-19 fostered an affable learning culture wherein we students could freely ask questions and seek clarification about all aspects of course material thus ensuring the synthesis of the various concepts being taught. Today, whilst our lecturers are making every effort to encourage us, students, to ask questions via email or discussion boards, many students myself included, are reluctant to do so, now, more so than ever.

In my opinion, a great degree of self-discipline is required to achieve the same grades working remotely. Personally, I am a creature of habit and once adapted to my new routine I worked quite well from home. The key for me was providing structure not only to my day but to my week: I worked consistently on weekdays and took Sundays to reflect and recuperate; ready to start afresh again on Monday morning.

I do not want to seem wholly pessimistic about the online learning platform; in the interest of balance, I have to reflect on some of the positive aspects attached to this new learning environment. I really benefited from having more time in which I could truly grasp concepts and read background literature aiding in my understanding of topics. Pre-recorded lectures allowed me to take detailed, methodical notes, pausing the lecture to write and do a quick search if I became confused or unclear about some aspect of the lecture.

I believe that the online learning forum certainly exacerbates the inequalities that already exist with our education system. As a student, I consider myself very lucky and privileged to have access to all of the technological devices essential to attain high grades whilst working remotely; I own a smartphone, laptop, textbooks, and my home has excellent broadband access. Furthermore, I live in a home environment conducive to study, affording me space for optimal concentration, productivity, and taking remote examinations. The college library is where most students go to knuckle down and accomplish the tasks at hand and it's difficult to recreate this space at home with so many opportunities for distraction. The library facilitates delineation between academic and home life both mentally and physically; online learning without this separation seems overwhelming at times.

Personally, one of my major apprehensions was the degree of uncertainty regarding how examinations would be carried out remotely. We received daily emails informing us of meetings between the relevant bodies and that all steps were being taken to ensure that online examinations would not impact our grades. A petition circulated among students calling for universities across the country to follow the actions of many universities in the UK and implement a "no detriment" policy to ensure grades would not suffer as a result of the COVID-19 pandemic. This did not occur; however, we were informed of a similar and an arguably equally fair strategy, whereby students unhappy with grades awarded following summer exams would be allowed to repeat uncapped in Autumn. This was followed promptly by emails from individual lecturers specifying requirements for each module. This consideration, and clarity by our lecturers, greatly eased the concerns of many of my classmates and myself and effectively helped to motivate us at a time when initial enthusiasm had begun to dwindle. Examinations were of an open book format focusing more on our understanding of content than the simple recall of facts.

Older generations may assume that my youth automatically implies I am a "technological genius"; however, unlike many students, I would consider myself quite traditional in my approach to learning and my study techniques. I tend to print off lecture slides, write all my notes by hand, and I refer to physical copies of textbooks rather than "e-books". I believe that my style of learning left me at a disadvantage when both learning and examinations were moved online. I often struggled with the novel mechanics of "speed-typing" during exams, and believe that those who were more tech savvy would be at an advantage. Some challenges were also presented with the exams that were to be handwritten, scanned and uploaded all within 120 mins; technical difficulties with failed scanning and uploading proving to be the main points of struggle.

One may have thought the usual pre-exam hype and the post-examination autopsy would be eliminated, but rather, these events occurred in a virtual sense, and to some extent were worse than ever before. Rather than comparing which questions we chose to answer and what information we included, the most common question asked in the year group chat was now "how many words did ye write?" The replies to this question led to an instant feeling of inadequacy. I found myself trying to reassure myself with the well-known phrase "quality over quantity" and hoped that answering the question asked was more important than including additional but irrelevant information.

The ultimate impact of online learning on students depends, I suppose, on the individual student. As I said, I'm one of the lucky ones, I'm driven and determined to do well, I have access to resources and a suitable environment to work in but I would have serious concerns for those who aren't as fortunate. I know that I will not look back on this semester as fondly as others; however, remote learning has not been all that bad for me. I certainly have not missed my hour-long morning commute, and at the time of my final exam, I had begun to adjust to this new examination format. I do hope that in time, through utilising all resources available and the expansion of our technological skills, we will adapt to and overcome the challenges presented by remote learning – if it is to be the consistent "new normal"!

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Obituary: John Bligh 1922 – 2020

John Bligh

I was standing by the window at a scientific meeting in 1983, admiring the view of the Honolulu coastline, and counting my lucky stars to be able to present my doctoral work at an international conference. After the ordeal of presenting, I spent the break exchanging pleasantries with an elderly scientist who was also admiring the view. With a look suggesting that I was probably unaware of this fact, he asked me if I knew what happened to Georg von Békésy after he received his Nobel Prize (for his discoveries in hearing). Having had a biomedical engineering background, I knew the history of the von Békésy up to the Nobel prize, but not thereafter. He smiled and suggested I should visit von Békésy laboratory (converted to a museum) at the University of Honolulu (which I did). This was how I met John Bligh, then about to take up an appointment at the University of Anchorage, just prior to retiring.

John Bligh studied physiology at University College London where he obtained a BSc and then a PhD in 1952 working with Otto Hutter. He then joined the Hannah Dairy Research Institute in Ayr, where he first became interested in the problems of temperature regulation. In 1957 he transferred to the Agricultural Research Council's Institute of Animal Physiology at Babraham, Cambridge, where he was Senior Principal Scientific Officer. Between 1972 and 1973 he held a Leverhulme Visiting Professorship in Peru, before moving to become the Director of the Institute for Arctic Biology in Fairbanks, Alaska from which he retired in 1985.

By that time, John had gained international recognition for his work in the area of temperature regulation. He is best known for his reciprocal cross inhibition (RCI) theory of temperature regulation where the balance between heat production and evaporative heat loss sets the body temperature. He considered the RCI theory as being a unifying theory, perhaps representing the functional unit in the homeostasis of all autonomic systems. He promoted this insightful idea religiously, to the extent that his colleagues even made a rubber stamp representing a diagram of his RCI theory, so that he could be more efficient in his back-of-the-envelope presentations.

The results of our work when I invited him to Simon Fraser University in 1986 further convinced him that perhaps the "set-point" theory, whilst a useful aid to the teaching of temperature regulation, was not accurate mechanistically, and he therefore modified his intricate model of temperature regulation to account for the inter-threshold range of core temperatures in which body temperature was regulated. As neatly summarised by Professor Romaine Harvey, while chairing John's invited presentation on temperature regulation at the 40th Anniversary meeting of The Physiological Society Climatic Physiology Group, "so, the salient feature of the set-point, is that it is neither a point, nor is it set?"

> "More questions? I already told them everything I know!"

John never confirmed or denied his relationship with the (in)famous Captain Bligh. He certainly shared the Captain's strict adherence to rules (in John's case, of science) and remarkable ability to navigate (for John, through the scientific literature). He was a stickler for grammar, and above all proper definitions. Not surprisingly he co-edited the first *Glossary of Terms for Thermal Biology* (published in the *Journal of Applied Physiology* in 1973). This publication remains, after several iterations, of great value to the field.

Amongst John Bligh's other major contributions was his book *Temperature regulation in mammals and other vertebrates* (also published in 1973). It is an extensive review (colloquially one would even heretically refer to it as "the bible") of the prevailing knowledge of temperature regulation. Whereas this book covers all aspects of mammalian temperature regulation, one of his final contributions focused on homeothermy, with a particular emphasis on his theory of RCI. The text "Mammalian homeothermy: an integrative thesis" was initially intended to be published as a book, but appeared as a special issue of the *Journal of Thermal Biology* (**23**, 143 – 258, 1998). This was his lasting legacy to the field of mammalian temperature regulation.

John Bligh was a true "gentleman scientist", a cheerful, uplifting man, generous and insightful in his advice, a delight to be with, not least because of his sense of humour. In response to the invitation from the Chairman for questions from the floor at the Climatic Group meeting, John's retort was: "More questions? I already told them everything I know!".

As a mentor, John taught us that, in research, the investment in people is much more important than investment in infrastructure and instrumentation. He was a powerful advocate for honesty in science. He will be remembered by all who had the privilege of working with him as a kind, approachable, and extremely helpful and supportive mentor. He always had time for people. His wisdom provided guidance not only in our research, but also in our daily interactions as scientists and colleagues, something that today is not always offered by mentors and not always appreciated by the mentored.

Written by Igor B Mekjavic (Department of Automation, Biocybernetics, & Robotics, Jozef Stefan Institute, Ljubljana, Slovenia), who was John Bligh's host, colleague, student, and most importantly - his friend.

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